# Evaluation of TMJ Bone Degeneration Using CBCT in Kennedy Class I and II Patients

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## ABSTRACT

**Objective:** To assess temporomandibular joint (TMJ) osseous degeneration in Kennedy Class I and II partially edentulous patients using cone beam computed tomography (CBCT).

**Study Design:** A descriptive study.

**Place and Duration of the Study:** Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Marmara University, Istanbul, Turkiye, between January and June 2023.

**Methodology:** CBCT images of 207 patients (55 males, 152 females; aged between 22 and 80 years) were retrospectively analysed. TMJ osseous degenerations were classified as flattening, erosion, depression, osteophyte formation, sclerosis, subchondral cysts, or ankylosis. Statistical analyses were performed using descriptive methods and comparative tests, including chi-square test, Fisher's exact test, and Yates' continuity correction.

**Results:** Flattening was the most prevalent degenerative change, observed in 21.3% of right and 39.1% of left TMJs. Degenerative changes were significantly more common in the left TMJ among females (59.9%) than males (41.8%, p = 0.021). In Kennedy Class I patients, the prevalence of right TMJ degeneration (51.2%) was significantly higher than in Class II patients (37.2%, p = 0.045).

**Conclusion:** CBCT evaluation revealed that TMJ degenerative changes, particularly flattening, were more prevalent on the left side, significantly associated with female gender and Kennedy Class I edentulism.

**Key Words:** *Temporomandibular joint, Partial edentulism, Cone beam computed tomography, Kennedy classification, Temporomandibular joint disorder*.

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## INTRODUCTION

Understanding the classification of partial edentulism is essential for evaluating both tooth loss and planning prosthodontic treatments. Kennedy's 1925 system classifies partial edentulism into four categories: Class I (KI) involves bilateral posterior edentulous areas, Class II (KII) refers to unilateral posterior edentulous areas, Class III describes a unilateral edentulous space bordered by teeth anteriorly and posteriorly, and Class IV consists of a single anterior edentulous space with posterior teeth remaining.[1]

Existing research highlights the impact of posterior tooth loss on the temporomandibular joint (TMJ), particularly the reduction in posterior joint space, which increases the risk of anterior disk displacement and TMJ disorders. Prolonged edentulism may contribute to TMJ remodelling.

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In addition to edentulism itself, several contributing factors, such as parafunctional habits (*e.g.*, bruxism), direct or indirect trauma, and prosthesis usage, can influence the onset and severity of TMJ degenerative changes. Parafunctional forces may increase mechanical load on the joint, while the absence or improper design of prostheses may lead to uneven occlusal stress distribution.[2,3]

Patients with KI and KII classifications are at heightened risk of TMJ degenerative changes, including condylar erosion and osteophyte formation. Accurate diagnosis is crucial for effective management, which typically involves non-surgical approa-ches such as physical therapy and splints, with surgical interventions reserved for severe cases. Diagnostic imaging tailored to the clinical context aids in evaluating joint morphology and function.[4,5]

Imaging options for TMJ evaluation include panoramic radiography, CT, MRI, ultrasound, and cone-beam computed tomography (CBCT). Panoramic radiography provides an accessible overview; however, it is limited by its two-dimensional nature. MRI is the gold standard for soft-tissue visualisation, while CBCT excels at assessing osseous structures, offering lower radiation exposure than conventional CT. Although CBCT cannot visualise soft tissues, its precision in detecting bone- related pathologies makes it a preferred modality.[6]

Studies affirm CBCT's diagnostic accuracy for detecting condylar fractures and osseous changes (OC), combining high-resolution imaging with reduced radiation.[7] Hara *et al*. reported its diagnostic utility in systemic joint conditions, such as juvenile idiopathic arthritis.[8]

Early detection of TMJ degeneration is essential for preventing progressive joint deterioration, functional impairment, and chronic pain. In some cases, early signs of temporomandibular disorders (TMD) may be incidentally detected in patients who do not present with any TMJ-related symptoms. Additionally, patients often overlook the potential impact of posterior tooth loss on TMJ health. Timely diagnosis enables appropriate treatment planning, including conservative interventions and the design of prosthetic appliances that minimise additional stress on the joint. Particularly in partially edentulous patients, recognising early OC can help guide rehabilitative strategies to restore occlusal support and preserve joint health.[9,10]

Although the impact of tooth loss on TMJ health and the diagnostic value of CBCT have been widely acknowledged, a distinct gap persists regarding the prevalence and patterns of TMJ degenerative changes in relation to Kennedy classifications. Existing studies often either focus on generalised edentulism or do not employ standardised classification systems. While CBCT-based evaluations of KI patients have been conducted by Ahmed *et al*.[11] and TMJ degeneration related to posterior tooth loss has been described by AlKhairAllah *et al*.[12] These investigations have not comprehensively assessed both KI and KII cases or provided a detailed characterisation of degeneration types. In light of the need for classification-based analyses highlighted in previous studies, this study aimed to evaluate TMJ bone degeneration in KI and KII partially edentulous patients using CBCT.

## METHODOLOGY

This descriptive study evaluated CBCT images from the archives of the Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Marmara University, Istanbul, Turkiye, between January and June 2023. Ethical approval was obtained from the Clinical Research Ethics Committee of Marmara University School of Medicine, Istanbul, Turkiye (Approval No. 09.2023.31; dated: 6 January 2023). The study included KI and KII partially edentulous patients aged between 22 and 80 years, with at least six months of posterior edentulism, no history of trauma, and no TMJ-affecting pathologies. Patients with motion artefacts in imaging, those with pathologies, such as cysts or tumours in the region of interest, and cases where TMJ was not included within the field of view were excluded from the study.

Although patients' edentulous status was documented during the initial clinical examination, individual records of clinical TMJ assessment were not consistently available and, therefore, could not be included in the analysis. All patients provided written informed consent prior to imaging, which included permission for the use of their anonymised data for research purposes. Only patients with a history of eden-tulism of at least six months were included to ensure that any observed TMJ changes had sufficient time to develop.

A priori power analysis was performed using G*Power software to estimate the required sample size. Based on 8 parameters (degrees of freedom = 7), an effect size (w) of 0.5, a significance level (α) of 0.05, and a desired power (1–β) of 0.99, the minimum required sample size was calculated as 117 participants. Subsequently, a post hoc analysis confirmed that the final sample of 207 patients yielded an achieved power of 0.99997, indicating that the sample size was sufficient for the study.

CBCT images were obtained using the Planmeca Promax 3D Mid CBCT system (Planmeca Oy, Helsinki, Finland) under standardised settings (90 kV,10 mA). OC in the mandibular condyle was evaluated and classified into eight categories: no changes, flattening, erosion, depression, osteophyte, sclerosis, subchondral cyst, and ankylosis. Both the right and left TMJs were assessed separately (Figure 1).

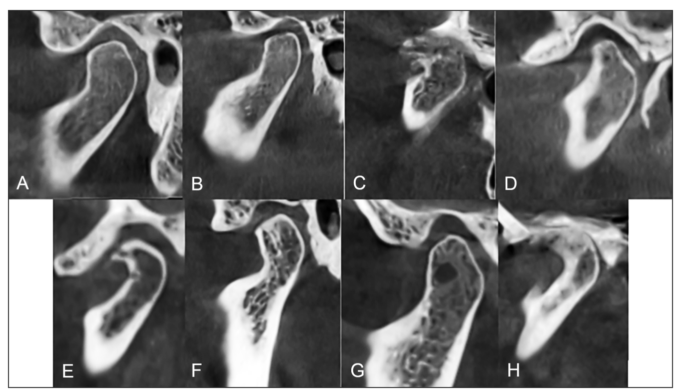


**Figure 1: Condyle categories (A) No changes, (B) Flattening, (C) Erosion, (D) Depression, (E) Osteophyte, (F) Sclerosis, (G) Subchondral cyst, and (H) Ankylosis.**

To ensure diagnostic consistency and reduce inter-observer variability, CBCT images were independently reviewed by three observers with varying levels of expertise: an associate professor with over 10 years of experience, a PhD candidate with 4 years, and a research assistant with 3 years in maxillofacial radiology. All assessments were conducted in consensus. In cases where uncertainty or discrepancy arose, a final decision was made by a professor with over 20 years of clinical and academic experience in the field. This consensus-based evaluation strategy was adopted to enhance diagnostic reliability. Each OC was defined based on previously established CBCT diagnostic criteria. Flattening was identified as a loss of the normal convexity of the condylar surface; erosion was characterised by localised radiolucent areas with reduced cortical bone density; osteophytes were described as marginal bony outgrowths beyond the cortical boundary. Other alterations, such as sclerosis, depression, subchondral cysts, and ankylosis, were also assessed using these radio-morphological criteria.

..Statistical analyses in this study were performed using IBM SPSS Statistics 22 software. Descriptive statistics (mean, standard deviation, frequency) were used to evaluate the data, while the chi-square test, Fisher's exact test, and Yates' continuity correction were used for comparisons. Statistical significance was set at $p < 0.05$. Given the retrospective design of the study, blinding procedures were not applicable; this limitation is acknowledged as a potential source of observational bias.

## RESULTS

The study included a total of 207 CBCT images from individuals aged 22 to 80 years, comprising 55 (26.6%) males and 152 (73.4%) females, with a mean age of 51.31 ± 11.89 years. Based on the Kennedy classification, 58.5% of the cases were classified as KII and 41.5% as KI (Table I). The broad age range observed in the sample should be considered in light of the continuing preference for tooth extraction over alternative treatments by some patients, which contributes to the inclusion of both younger and older individuals in studies of this nature.

**Table I: Distributions of study parameters.**

| **Study parameters** | | **n** | **%** |
|---|---|---|---|
| Kennedy classification | KI | 86 | 41.5 |
| | KII | 121 | 58.5 |
| OC (right TMJ) | Present | 89 | 43 |
| | Not present | 118 | 57 |
| Right TMJ changes | Flattening | 44 | 21.3 |
| | Erosion | 25 | 12.1 |
| | Depression | 13 | 6.3 |
| | Osteophyte | 35 | 16.9 |
| | Sclerosis | 6 | 2.9 |
| | Subchondral cyst | 14 | 6.8 |
| | Ankylosis | 1 | 0.5 |
| Right TMJ changes combinations (n = 89) | Depression | 7 | 7.9 |
| | Flattening-osteophyte | 4 | 4.5 |
| | Flattening-subchondral cyst | 1 | 1.1 |
| | Flattening | 22 | 24.7 |
| | Flattening-depression | 2 | 2.2 |
| | Flattening-depression-osteophyte | 1 | 1.1 |
| | Flattening-erosion | 3 | 3.4 |
| | Flattening-erosion-depression-subchondral cyst | 1 | 1.1 |
| | Flattening-erosion-osteophyte | 3 | 3.4 |
| | Flattening-erosion-osteophyte-subchondral cyst | 2 | 2.2 |
| | Flattening-erosion-subchondral cyst | 1 | 1.1 |
| | Flattening-osteophyte | 3 | 3.4 |
| | Flattening-osteophyte-subchondral cyst | 1 | 1.1 |
| | Erosion | 5 | 5.6 |
| | Erosion-depression | 2 | 2.2 |
| | Erosion-osteophyte | 5 | 5.6 |
| | Erosion-osteophyte-subchondral cyst | 1 | 1.1 |
| | Erosion-osteophyte-subchondral cyst-ankylosis | 1 | 1.1 |
| | Erosion-sclerosis-subchondral cyst | 1 | 1.1 |
| | Osteophyte | 13 | 14.6 |
| | Osteophyte-subchondral cyst | 1 | 1.1 |
| | Sclerosis | 5 | 5.6 |
| | Subchondral cyst | 4 | 4.5 |
| OC (left TMJ) | Present | 114 | 55.1 |
| | Not Present | 93 | 44.9 |
| Left TMJ changes | Flattening | 81 | 39.1 |
| | Erosion | 30 | 14.5 |
| | Depression | 16 | 7.7 |
| | Osteophyte | 23 | 11.1 |
| | Sclerosis | 4 | 1.9 |
| | Subchondral cyst | 6 | 2.9 |
| | Ankylosis | 2 | 1.0 |
| Left TMJ changes combinations (n = 114) | Ankylosis | 1 | 0.9 |
| | Depression | 7 | 6.1 |
| | Flattening | 50 | 43.9 |
| | Flattening-depression | 6 | 5.3 |
| | Flattening-erosion | 13 | 11.4 |
| | Flattening-erosion-osteophyte | 3 | 2.6 |
| | Flattening-erosion-sclerosis | 1 | 0.9 |
| | Flattening-erosion-subchondral cyst | 1 | 0.9 |
| | Flattening-osteophyte | 6 | 5.3 |
| | Flattening-sclerosis | 1 | 0.9 |
| | Erosion | 3 | 2.6 |
| | Erosion-depression | 3 | 2.6 |
| | Erosion-osteophyte | 3 | 2.6 |
| | Erosion-osteophyte-ankylosis | 1 | 0.9 |
| | Erosion-osteophyte-subchondral cyst | 2 | 1.8 |
| | Osteophyte | 8 | 7.0 |
| | Sclerosis | 3 | 2.6 |
| | Subchondral cyst | 2 | 1.8 |

**Table II: Evaluations by gender.**

| Study parameters | | Male (n = 55) n (%) | Female (n = 152) n (%) | p-values |
|---|---|---|---|---|
| Kennedy classification | KI | 22 (40%) | 64 (42.1%) | [1]0.786 |
| | KII | 33 (60%) | 88 (57.9%) | |
| OC (right TMJ) | Present | 26 (47.3%) | 63 (41.4%) | [1]0.455 |
| | Not present | 29 (52.7%) | 89 (58.6%) | |
| Right TMJ changes | Flattening | 12 (21.8%) | 32 (21.1%) | [2]1.000 |
| | Erosion | 5 (9.1%) | 20 (13.2%) | [2]0.581 |
| | Depression | 6 (10.9%) | 7 (4.6%) | [3]0.112 |
| | Osteophyte | 9 (16.4%) | 26 (17.1%) | [2]1.000 |
| | Sclerosis | 1 (1.8%) | 5 (3.3%) | [3]1.000 |
| | Subchondral cyst | 6 (10.9%) | 8 (5.3%) | [3]0.207 |
| | Ankylosis | 1 (1.8%) | 0 (0%) | [3]0.266 |
| OC (Left TMJ) | Present | 23 (41.8%) | 91 (59.9%) | [1]0.021* |
| | Not present | 32 (58.2%) | 61 (40.1%) | |
| Left TMJ changes | Flattening | 15 (27.3%) | 66 (43.4%) | [2]0.052 |
| | Erosion | 4 (7.3%) | 26 (17.1%) | [2]0.121 |
| | Depression | 5 (9.1%) | 11 (7.2%) | [3]0.769 |
| | Osteophyte | 5 (9.1%) | 18 (11.8%) | [2]0.760 |
| | Sclerosis | 0 (0%) | 4 (2.6%) | [3]0.575 |
| | Subchondral cyst | 1 (1.8%) | 5 (3.3%) | [3]1.000 |
| | Ankylosis | 1 (1.8%) | 1 (0.7%) | [3]0.462 |

*[1]Chi-square test. [2]Continuity (Yates) correction. [3]Fisher's exact test, * p<0.05.*

**Table III: Evaluations by Kennedy classification.**

| Study parameters | | KI (n = 86) n (%) | KII (n = 121) n (%) | p-values |
|---|---|---|---|---|
| OC (right TMJ ) | Present | 44 (51.2%) | 45 (37.2%) | [1]0.045* |
| | Not present | 42 (48.8%) | 76 (62.8%) | |
| Right TMJ changes | Flattening | 23 (26.7%) | 21 (17.4%) | [1]0.104 |
| | Erosion | 10 (11.6%) | 15 (12.4%) | [2]1.000 |
| | Depression | 2 (2.3%) | 11 (9.1%) | [2]0.092 |
| | Osteophyte | 14 (16.3%) | 21 (17.4%) | [2]0.988 |
| | Sclerosis | 3 (3.5%) | 3 (2.5%) | [3]0.694 |
| | Subchondral cyst | 6 (7%) | 8 (6.6%) | [2]1.000 |
| | Ankylosis | 0 (0%) | 1 (0.8%) | [3]1.000 |
| OC (left TMJ) | Present | 49 (57%) | 65 (53.7%) | [1]0.642 |
| | Not present | 37 (43%) | 56 (46.3%) | |
| Left TMJ changes | Flattening | 37 (43%) | 44 (36.4%) | [1]0.333 |
| | Erosion | 10 (11.6%) | 20 (16.5%) | [2]0.431 |
| | Depression | 7 (8.1%) | 9 (7.4%) | [2]1.000 |
| | Osteophyte | 8 (9.3%) | 15 (12.4%) | [2]0.636 |
| | Sclerosis | 4 (4.7%) | 0 (0%) | [3]0.029* |
| | Subchondral cyst | 2 (2.3%) | 4 (3.3%) | [3]1.000 |
| | Ankylosis | 0 (0%) | 2 (1.7%) | [3]0.512 |

*[1]Chi-square test. [2]Continuity (Yates) correction. [3]Fisher's exact test, * p<0.05.*

Analysis of OC revealed that 43% of right TMJs and 55.1% of left TMJs presented with at least one degenerative feature, indicating a higher prevalence of degenerative changes on the left side. Flattening was the most commonly observed alteration in both joints (21.3% right, 39.1% left), followed by osteophyte formation (16.9% right, 11.1% left) and erosion (12.1% right, 14.5% left). Other changes, such as depression (6.3% right, 7.7% left), subchondral cysts (6.8% right, 2.9% left), and sclerosis (2.9% right, 1.9% left), occurred less frequently. Ankylosis was rare in both joints, observed in only one case on the right and two cases on the left (Table I).

Degenerative combinations were more frequent and varied in the left TMJ (n = 114) compared to the right (n = 89). On the right side, flattening was most frequently found alone (24.7%) or combined with osteophyte formation (4.5%) and erosion (3.4%). Complex patterns, including flattening, erosion, osteophyte, and subchondral cysts in various combinations, were observed in low frequencies (1.1–2.2%). On the left side, flattening as an isolated finding was more dominant (43.9%), followed by its combination with erosion (11.4%) and osteophyte formation (5.3%). Rare patterns, such as erosion with osteophyte and ankylosis or flattening with erosion and sclerosis, were observed. The higher diversity and frequency of changes in the left TMJ may suggest asymmetrical functional loading, possibly due to dominant chewing habits or mandibular asymmetry (Table I).

Gender stratified analysis revealed no statistically significant differences between males and females in Kennedy classification distribution (KI *vs*. KII) as well as in the presence of degenerative findings in the right TMJ (p >0.05). However, osseous degeneration in the left TMJ was significantly more frequent in females (59.9%) than males (41.8%, p = 0.021). Although some individual findings, such as flattening, erosion, and osteophyte formation, were more common in females, none of these reached statistical significance (p >0.05, Table II).

According to Kennedy classification, OC in the right TMJ was significantly more frequent in KI (51.2%) than in KII (37.2%) patients (p = 0.045). Specific degenerative changes, such as flattening, erosion, and osteophyte formation, showed no statistically significant differences between the two groups (p >0.05). On the left side, the prevalence of sclerosis was significantly higher in KI patients (4.7%) compared to KII (0%, p = 0.029). Other degenerative patterns showed no statistical variation between the groups (p >0.05). The overall findings suggest that degeneration occurs bilaterally but is more frequent and complex in the left TMJ, particularly among females and KI patients. Flattening was the most common alteration and often co-occurred with other degenerative changes, suggesting that it may represent an early or primary sign of TMJ adaptation (Table III).

## DISCUSSION

TMJ is a dynamic and adaptable structure; however, changes in loading patterns caused by partial edentulism can lead to degenerative changes. Rawat *et al*., in a systematic review of 13 studies, found that TMJ disorder severity and frequency increased with the extent of tooth loss, underscoring the impact of reduced occlusion and vertical dimension.[13]

CBCT is one of the most preferred imaging modalities for TMJ assessment, providing high-resolution, three-dimensional visualisation of osseous structures with reduced distortion and minimal superimposition. Multiple studies have supported its effectiveness in detecting early and subtle degenerative changes. Gharavi *et al*. highlighted the superiority of CBCT over other modalities in identifying osseous abnormalities, while Hatcher reported that changes in mandibular and TMJ morphology due to ageing and altered occlusal loading could be reliably captured using this technique.[14,15] The National Academies of Sciences further emphasised the diagnostic value of CBCT, particularly in recognising changes that may not be visible on conventional radiographs.[16] This is consistent with the findings of Im *et al*., who demonstrated that CBCT had greater accuracy and reliability than panoramic imaging in detecting bony lesions in TMJ osteoarthritis.[17]

When examining degenerative changes within TMJ, several contributing factors have been identified in the literature. In the study by Santana-Mora *et al*., habitual unilateral chewing was found to be associated with increased degenerative changes on the affected side, including steeper condylar path angles and flatter lateral guidance.[18] These findings suggest that functional asymmetry may play a role in joint remodelling. The higher prevalence and complexity of left-sided degenerative alterations observed in the present study may reflect a similar pattern of uneven functional loading.

Flattening was identified as the most frequent TMJ degeneration in this study, consistent with the findings from Alexiou *et al*. and Campos *et al*., who also noted erosion and osteophyte formation as prominent degenerative changes.[19,20] Supporting this, Massilla Mani and Sivasubramanian conducted a CT-based evaluation of 30 TMJs in elderly patients with temporomandibular dysfunction and reported that condylar alterations—primarily erosion, flattening, sclerosis, and osteophyte formation—were the most common degenerative features. Their results are consistent with the results of the current study, in which early-stage degenerative changes were frequently observed. The high incidence of such alterations in both investigations highlights the progressive nature of TMJ degeneration and the importance of early identification and intervention.[21]

When considering gender-related differences, it is worth noting that, although distribution in the present study was not entirely balanced, the observed patterns may partly reflect the higher predisposition of females to TMD. Shet *et al*. reported a significantly higher prevalence of TMD symptoms among partially edentulous female patients, including joint clicking, mandibular deviation, tenderness, and masseter muscle involvement.[22] These clinical signs were also found to be associated with longer durations of edentulousness, particularly in cases exceeding five years. In the present study, degenerative changes in the TMJ were more frequently observed in female participants. This finding may reflect similar gender-related biological factors, including hormonal influences and time-dependent vulnerability to joint dysfunction. However, future studies with a more balanced gender distribution and larger sample sizes are necessary to more accurately understand the extent and underlying mechanisms of these differences.

When examining studies based on the Kennedy classification, relevant findings provide additional context for interpreting the current results. AlKhairAllah *et al*. evaluated CBCT images of 200 KI and KII patients and detected degenerative changes in 76% of cases. Flattening emerged as the most common alteration, particularly in males with KII edentulism.[12] However, no significant associations were found between gender, Kennedy classification, or TMJ side.[22] The increased degenerative changes in the right TMJ of KI patients suggest that the extent and distribution of edentulism significantly influence TMJ pathology. These findings highlight the critical role of prosthetic rehabilitation in mitigating the adverse effects of partial edentulism on TMJ health.[12,23]

In the study by Yanikoglu and Guldag, the condyle/fossa relationship was examined in KI and KII partially edentulous patients.[2] It was observed that posterior joint space narrowing was more prominent in KI individuals, indicating greater biomechanical stress in the absence of bilateral posterior support. In the present study, increased degenerative changes in the KI group—especially on the right TMJ—can be considered consistent with this finding, suggesting that the loss of posterior occlusal contact contributes to joint remodelling.

Although this study enabled a detailed analysis of osseous degenerative changes in the TMJ—both as isolated findings and in combination—it is important to acknowledge several limitations. Due to its retrospective design, causal relationships could not be established, and potential confounding variables could not be fully controlled. Furthermore, clinical data on masticatory habits, occlusal dynamics, and parafunctional behaviours such as bruxism were not consistently available in the archived records, preventing their inclusion in the analysis. Another limitation concerns the gender distribution within the sample, which was not balanced and may therefore affect the generalisability of gender-related findings.[24]

In addition to high-resolution CBCT imaging for detailed assessment of OC, the integration of MRI could provide valuable insight into associated soft tissue alterations. Incorporating comprehensive clinical examinations would also allow for a more holistic evaluation of both functional and structural aspects of the joint. Such multi-faceted approaches are likely to yield more robust and generalisable findings, contributing to improved diagnostic and treatment strategies.

## CONCLUSION

This study's findings underline the importance of timely prosthetic rehabilitation and suggest that early detection of TMJ alterations may aid in preserving joint function and preventing further deterioration. To strengthen the current understanding of TMJ degeneration, future studies should adopt prospective, comparative designs that include a more balanced gender distribution.

**ETHICAL APPROVAL:**
Ethical approval was obtained from the Clinical Research Ethics Committee of Marmara University School of Medicine, Istanbul, Turkiye (Approval No. 09.2023.31; dated: 6 January 2023).

**PATIENTS' CONSENT:**
Written informed consent was obtained from all patients at the time of their initial CBCT imaging, including approval for the use of anonymised data in future research.

**COMPETING INTEREST:**
The authors declared no conflict of interest.

**AUTHORS' CONTRIBUTION:**
HY: Methodology, investigation, data curation, writing, review, and editing.
GK, FNP: Methodology, validation, writing, review, and editing.
SYU: Methodology, investigation, and writing of the original draft.
All authors approved the final version of the manuscript to be published.

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